Mapping the Spatial Dynamics in Optically Significant Nephaloid Layers using Autonomous Underwater Gliders during MIREM

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LONG-TERM GOALS

Our long-term goal is to develop a coherent understanding of the dynamics and optics of nepheloid layers. To accomplish this, particle composition characteristics will be resolved with the relevant physical forcing mechanisms across a wide range of time and space scales. For the first time, as a result of recent efforts by these investigators, we now have the deployment platform and optical sensing technology that can adequately address this critical problem (Glenn et al. 2004). This work is submitted in collaboration with E. Boss, J. Trowbridge, P. Hill, and T. Milligan (ONR-OB), who are looking at the effects of aggregation and disaggregation on the particle size distribution in nepheloid layers at the Martha's Vineyard Coastal Observatory (MVCO). This work is also in collaboration C. Jones (ONR-PO), who is developing new autonomous sensing capabilities for Mine Counter Measure applications.

OBJECTIVES

Specific objectives of this research include the following:

1) We propose to use a fleet of optically-outfitted gliders to spatially map the presence of nepheloid layers to complement a series fixed platform observations to be measured at the Martha's Vineyard Coastal Observatory (MVCO). At the MVCO, a combination of bottom-mounted and profiling sensors will characterize the particle size distribution and the optical and acoustical properties in the water column near the seabed.
2) Partake in the April MIREM mine counter measure effort of the coast in Virginia in collaboration with the navy and Metron Inc..

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APPROACH

The research in the recent year consisted of the following tasks:

Task 1: We used a fleet of optically-outfitted gliders to spatially map the presence of nepheloid layers to complement fixed platform observations. With ONR support a bio-optical glider has been developed. In collaboration with Michael Twardowski (WetLabs Inc.) and Clayton Jones (Webb Research Inc.), we have integrated the Scattering Attenuation Meter (SAM) and Eco Pucks into Webb gliders. The SAM was outfitted with a single wavelength (red). Standard PUCK systems are outfitted with 2 wavelengths of backscatter and either chlorophyll or colored dissolved organic fluorescence. Field operations were conducted in late spring and summer (see below Task 2); however we have focused on mapping nepheloid layers as much as possible and therefore have kept gliders flying in variety of water masses in addition to the formal deployments listed below (Figure 1). All glider sampling involved a flexible adaptive sampling strategy with gliders being as the environment evolved during the deployment.

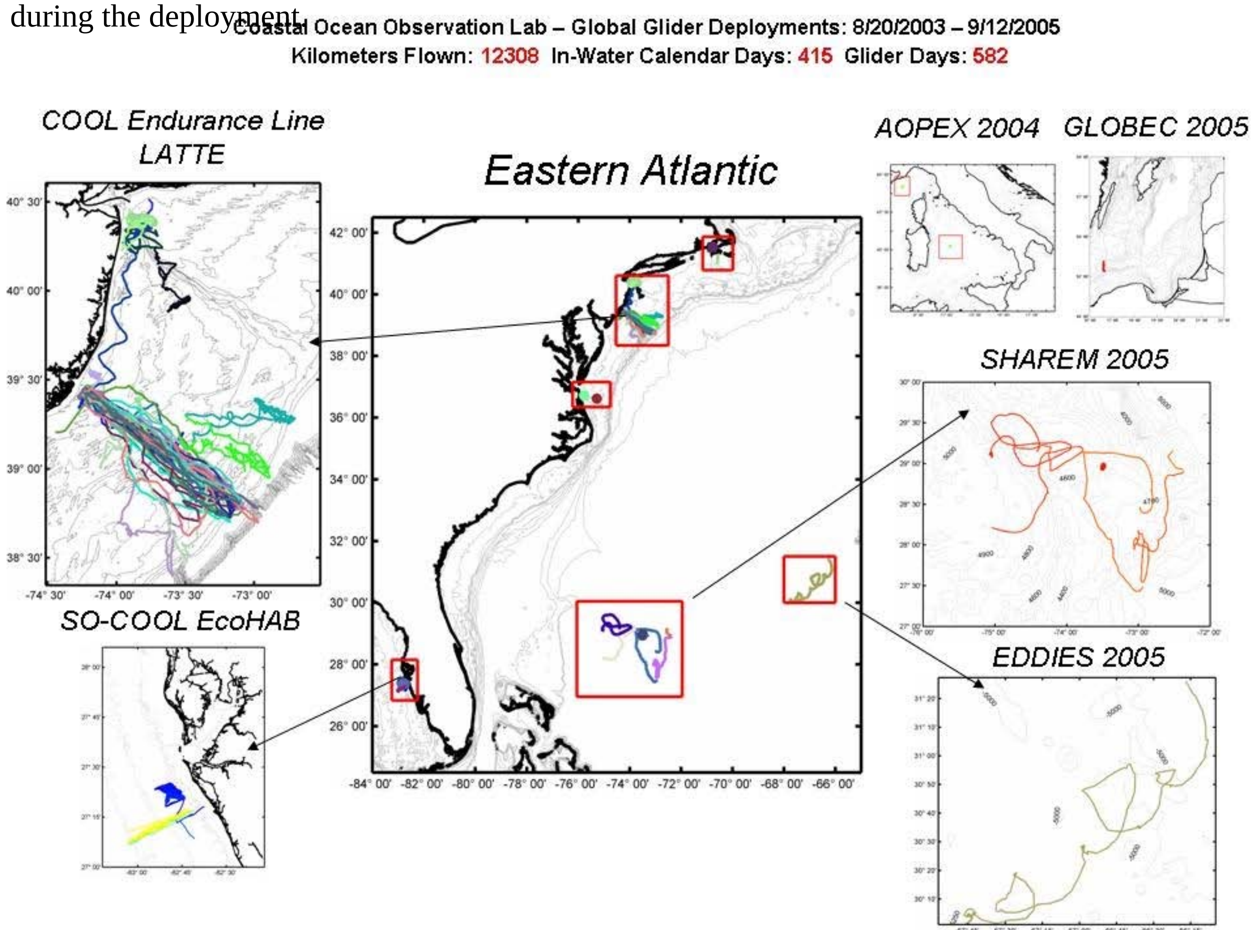

Figure 1. Glider deployments globally not including current deployments being conducted in the Pacific and at Martha's Vineyard.

Task 2: Partake in the April MIREM mine counter measure effort of the coast in Virginia in collaboration with the Navy and Metron Inc. Gliders were flown as part of the MIREM MCM effort in april 2005. An exercise was conducted using the AQS-24 Laser Line Scan (LLS) system in VACAPES with HM-14 operating from Norfolk. The goal of this exercise was to measure

performance of the AQS-24 LLS system. Specifically for the LLS, the performance issues focused on the reacquisition and identification probabilities in a diverse range of coastal waters. The plan included reacquisition and identification of various mine shapes (large & medium-size cylindrical and 2 'stealthy' shapes) with the LLS in two water depths (about 50 and 100 ft). This goal is to evaluate the effects of ambient light on image contrast and its impact on identification that would detected by the airborne LLS system. The second effort in late summer focused on flying a Glider during a highly instrumented zone off the Martha's Vineyard Cabled Observatory (MVCO). For that effort we are deploying two optically-outfitted gliders to spatially map the presence of nepheloid layers to complement the fixed platforms which include a combination of bottom-mounted and profiling sensors will characterize the particle size distribution and the optical and acoustical properties in the water column near the seabed. These measurements are also complemented by ongoing measurements of stress, velocity, and stratification at the MVCO site.

Figure 2. A Webb glider and a naval helicopter LLS system during the 2005 MiREM field efforts.

WORK COMPLETED

The MIREM effort was conducted in April 2005. For this effort, a bio-optical glider was deployed during helicopter LSS surveys (Figure 2). The data is supplied to the *EODES-3* which is an electro-optic sensor and systems model that can provide performance predictions for specific systems in a given environment, determine operational settings that maximize the area search rate for a prescribed performance level, and produce simulated images for operator training. The data was ingested the Metron's EODES-3 models. Data was also passed to SAIC and NAVOCEANO to begin modifications of the the MEDAL system to accommodate the glider data. The data was used to estimate the efficacy of the LLS to detect mine-like objects deployed on the sea floor during the MIREM effort. For the MVCO, gliders were deployedat the beginning of September. The gliders still remain at sea, and will continue to fly the MVCO site through October. This will ensure data is collected through the majority of the hurricane and tropical storm season in the NorthEast United States.

RESULTS

During MIREM a diverse range of optical properties were encountered. These results impacted the ability to detect bottom objects. The impact of the in situ optics is illustrated in Figure 3. The optical properties on April 24 were characterized by the presence of a thick nepheloid layer which is in contrast to April 26 when no nepheloid layer was observed. The clear panels show an object's potential detection in clearest waters. The real water conditions show the potential to detect the object on April 24th and 26th offhsore Virginia. Results show the potential applications for the Navy. Data analysis continues on this data set.

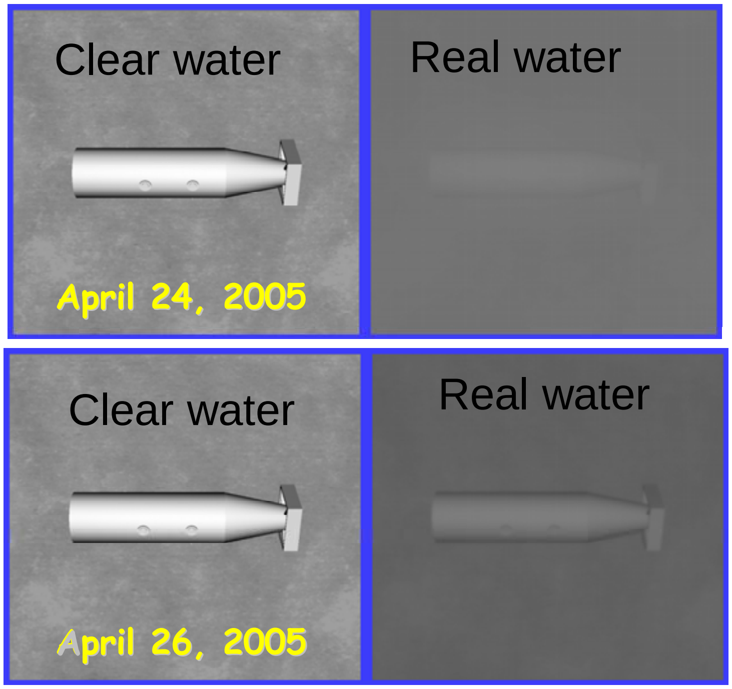

Figure 3. The impact of the *in situ* optics on the efficacy of object detection on the benthos. Results derived from optical data and Metron's EODES-3.

The MVCO glider has been flying for 2.5 weeks. The goal is complement this deployment with a 2 glider operation in October. The path of the MVCO glider during the September deployment is provided in Figure 4. During this deployment of the glider over 4000 vertical casts have been collected. The major challenge during the deployment has been to fly in the face of the strong currents and tides present at MVCO. To this end, we have successfully navigated this area by surfing tidal currents. In the coming years efforts will focus on automating some of these adaptive efforts using a standard tidal model. The optical data should be interesting given that the experimental area was impacted by tropical storm Ophelia. This effort also provided the funds to develop an automated web based GUI (Figure 5) which now allows operators to remotely access Glider engineering data and modify the Gliders flight strategies. We will transition this GUI to the wider community in 2005-2006. Currently research groups at Oregon State University and the University of Maine have shown interest in using this GUI to anchor their Glider efforts in the coming year. During this Glider deployment an optical calibration data set for the SAM was collected by Mike Twardowski using a discrete optical profiling system. This discrete data will critical to analysis to begin as gliders finish at MVCO at the end of October.

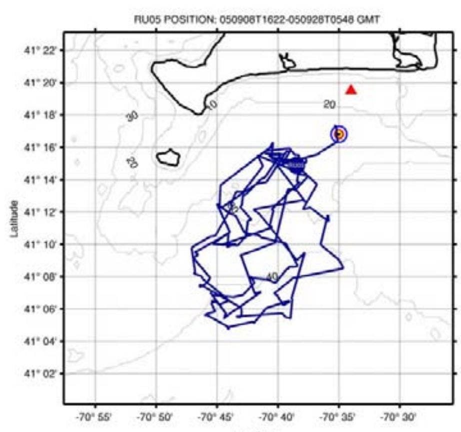

Figure 4. Glider flight path up to September 28 2005 at the MVCO nepheloid layer experiment..

IMPACT/APPLICATIONS

The Navy's mission has transitioned from a deep blue water tactical theatre to a littoral environment; however present Naval operational capabilities do not have the required data fidelity to deal with the complexity of coastal waters. These shortcomings are compounded as traditional sampling approaches are quickly compromised in denied access regions. The development of a long duration covert capability for collecting environmental (hydrographic and optical) data will offer a new paradigm in solving this problem. Using mine counter measures as an example, optical data would feed back on submersed and aircraft laser line scan mission planning by impacting the effective depth at which the laser can "see". If the environmental characterization is performed over relevant scales the applications will assist real world missions,

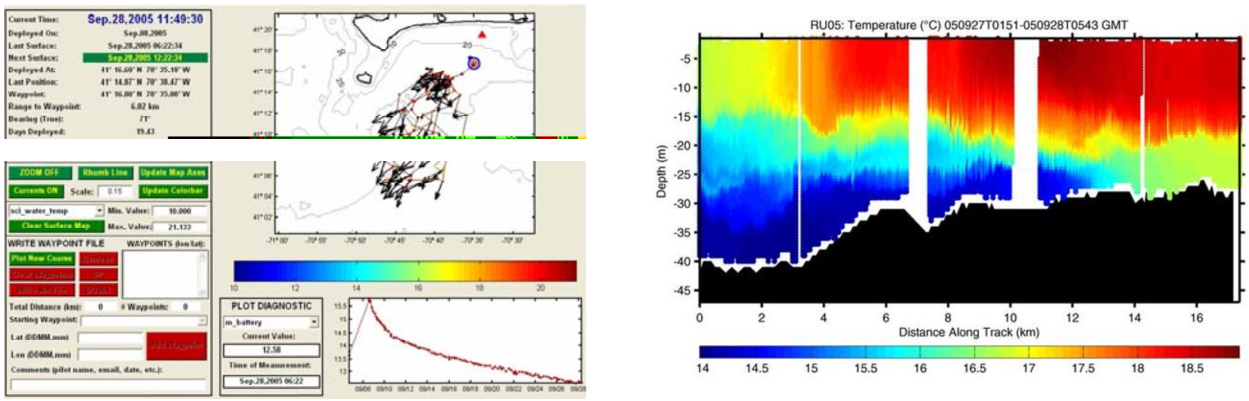

Figure 5. A) the web based GUI allowing operators to easily access glider engineering data and re-direct the Gliders mission. B) One example of the data density collected during a single glider transect during the MVCO deployment in September 2005. Optical data was not shipped to shore during this mission in order to minimize periods communicating at the given the strong currents in this location.

including mine detection and mine-counter measures, Special Forces operations, amphibious landings, shallow water anti-submarine warfare and force protection from terrorism

RELATED PROJECTS

The data is being freely shared with Metron, Anteon, Surface Warfare Development and NAVOCEANO. Discussion has been initiated how glider optical data might integrated into the ONR WOOD database. Data will be burned to data CD's and will be made available via one-way FTP. Ongoing field efforts also distribute data in real-time over the world-wide-web (currently the site routinely has over 150,000 hits/day) by the general public, Naval METOC groups, NAVO, NOAA, and the U.S. Coast Guard. The data will be distributed to fellow PIs from WHOI and Dalhousie MVCO OASIS resuspension experiments. Developing the optical capability for gliders will directly benefit a recently funded Major University Research Initiative (MURI) which will develop a data assimilative physical-optical modeling-observation system consisting of an ensemble of optical models of varying complexity. This MURI will study the regulation of ocean color for a broad western boundary continental shelf with a specific focus on regions of high optical variability (fronts), which coincides with regions of high acoustic uncertainty.

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PUBLICATIONS

One publication has been submitted and is currently under review. The manuscript was submitted to the Journal of Underwater Robotics. **Schofield**, **O**., Kohut, J., Aragon, D., Creed, L., Haldeman, C., Kerfoot, J., Roarty, H., Jones, C., Webb, D., Glenn, S. M. Sloccum Gliders: Robust and ready. Journal of Underwater Robotics (submitted)